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SPACE SHUTTLE

Solid Rocket Motors
Thiokol Corporation

TWR 50212

EVALUATION OF EA-934NA with 2.5% CAB-O-SIL
FINAL REPORT

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Evaluation of EA-934NA with 2.5% Cab-O-Sil

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1.0 INTRODUCTION

Currently, Hysol adhesive EA-934NA is used to bond the Field Joint Protection System on the Shuttle rocket motors at Kennedy Space Center. However, due to processing problems, an adhesive with a higher viscosity is needed to alleviate these difficulties. One possible solution is to add Cab-O-Sil to the current adhesive. This study (being performed under ETP-0610) looks at the adhesive strength and bond strengths that can be obtained when 2.5% Cab-O-Sil is added to adhesive EA-934NA and tested over a range of test temperatures from -20° to 300°F.

2.0 OBJECTIVE

To evaluate the tensile adhesion strength, lap shear strength and tensile properties that are obtained when 2.5% Cab-O-Sil is added to Hysol adhesive EA-934NA and is tested over a test temperature range of from -20° to 300°F.

3.0 SUMMARY

Tensile adhesion button and lap shear specimens were bonded to D6AC steel and uniaxial tensile specimens (testing for strength, initial tangent modulus, elongation and Poisson's ratio) were prepared using Hysol adhesive EA-934NA with 2.5% Cab-O-Sil added. These specimens were tested at -20°, 20°, 75°, 100°, 125°, 150°, 200°, 250° and 300°F, respectively. Additional tensile adhesion button specimens bonding Rust-Oleum primed and painted D6AC steel to itself and to cork using adhesive EA-934NA with 2.5% Cab-O-Sil added were tested at 20°, 75°, 125°, 200° and 300°F, respectively. Results generally show decreasing strength values with increasing test temperatures. The bond strengths obtained using cork as a substrate were totally dependent on the cohesive strength of the cork.

4.0 CONCLUSIONS

From the results obtained it can be concluded that strong bonds can be obtained when using adhesive EA-934NA with 2.5% Cab-O-Sil added. It can also be concluded that the bond to cork with this adhesive is stronger than the cork over the temperature range of -20° to 300°F tested.

5.0 RECOMMENDATION

It is recommended that Hysol adhesive EA-934NA with 2.5% Cab-O-Sil added be used to bond the redesigned Field Joint Protection System if other processing parameters of this adhesive are acceptable.

6.0 DISCUSSION

D6AC steel tensile adhesion button specimens were grit blasted, bonded together using both a minimum bondline and 30-mil Teflon coated steel spacers to control the bondline when using adhesive EA-934NA with 2.5% Cab-O-Sil added. The specimens were then put under tension using shrink tape. The adhesive was then cured for seven days minimum at room temperature. The specimens (five per test temperature) were then tested at test temperatures of -20°, 20°, 75°, 100°, 125°, 150°, 200°, 250° and 300°F, respectively and at a test speed of 0.05 in./min. Other D6AC tensile adhesion button specimens were coated with Rust-Oleum's zinc rich primer and white paint and then cured for 12 hours at 300°F. The painted surface was lightly abraded, wiped with a methyl chloroform dampened Rymplecloth and then bonded to another Rust-Oleum painted button or a button to which cork had been bonded to using adhesive EA-934NA with 2.5% Cab-O-Sil added using both a minimum and 30-mil bondline. The specimens were then tested at test temperatures of -20°, 75°, 125°, 200° and 300°F, respectively and at a test speed of 0.05 in./min.

For the lap shear specimens, D6AC steel panels 1/4-inch thick were grit blasted, bonded together with a minimum bondline using adhesive EA-934NA with 2.5% Cab-O-Sil added. Weights were applied to the panels during cure. The adhesive was then cured for seven days minimum at room temperature. The bonded panels were then cut into individual strips using the abrasive water jet and then machined to their final configuration. The specimens (five per test temperature) were then tested at test temperatures of -20°, 20°, 75°, 100°, 125°, 150°, 200°, 250° and 300°F, respectively and at a test speed of 0.05 in./min.

For the uniaxial test specimens, adhesive EA-934NA with 2.5% Cab-O-Sil added was vacuum cast onto Teflon coated panels using 1/8-inch thick Teflon coated steel windows to control the final adhesive thickness. A second panel was then used to compress the adhesive to its final thickness. The adhesive panels were then cured for a minimum of seven days at room temperature. After cure the specimens were cut into strips, routered to their final configuration and the edges lightly sanded. The specimens (five per test temperature) were then tested at test temperatures of -20°, 20°, 75°, 100°, 125°, 150°, 200°, 250° and 300°F, respectively and at a test speed of 2.0 in./min.

The specimens were tested for ultimate strength, initial tangent modulus, strain and Poisson's ratio. Poisson's ratio was not performed at the test temperatures of 200°F or higher due to equipment limitations.

The tensile adhesion button test results as shown in Table I and graphically in Figures 1, 2, and 3 generally show decreasing bond strengths with increasing test temperature. However, the the bond strength at -20°F for a 30-mil bondline does show a slight decline compared to the data at 20°F due to the brittleness of the adhesive at lower test temperatures. The results show that the bond to the paint is also dependent on the strength of the paint itself and for the cork specimens is dependent only on the strength of the cork as the failure mode was 100% cohesive in the cork at all test temperatures.

The lap shear results as shown in Table II and graphically in Figure 4 show the same general trend as for the 30-mil bondline in the tensile adhesion button results except a small rise in strength values at 200°F probably caused by experimental data variation.

The uniaxial tensile test specimen data results are shown in Table III and graphically in Figure 5 for the tensile strength, Figure 6 for the initial tangent modulus and Figure 7 for the percent elongation at failure. The highest percent elongation is achieved at a test temperature of 150°F with lower percent elongation results at lower and higher test temperatures. The tensile data also show a drop in strength at -20°F when compared to 20°F due to the brittleness of the adhesive as occurred for the tensile adhesion and lap shear data for the bond to steel.

The overall results suggest that the addition of 2.5% Cab-O-Sil to EA-934NA still results in an adhesive with high strength values and could be used on Field Joint Protection System assuming other processing requirements are achieved.

7.0 RESULTS

The results for the tensile adhesion button data of D6AC steel to D6AC steel, Rust-Oleum primed and painted D6AC steel to Rust-Oleum primed and painted D6AC steel and cork with minimum and 30-mil bondlines when using adhesive EA-934NA with 2.5% Cab-O-Sil are shown in Table I. The results show the substrate, test temperature strength, coefficient of variance, number of specimens making up the results and the failure mode. The results are also shown graphically in Figures 1, 2, and 3. The results for the D6AC steel to D6AC steel lap shear specimens are shown in Table II and graphically in Figure 4. Results for the uniaxial tensile specimens shown in Table III include the test temperature, cross-head speed, strength, initial tangent modulus, strain, Poisson's ratio, coefficient of variance for each value and number of specimens making up the data. The results for the strength, modulus and elongation are also shown graphically in Figures 5, 6, and 7, respectively.

TABLE I

Tensile Adhesion Button Bond Strength
of EA-934NA with 2.5% Cab-O-Sil
(Test Speed 0.05 inches/minute)

SUBSTRATE	Test Temp. (°F)	STRENGTH (psi)	C.V. (%)	No. Tested	Failure Mode
MINIMUM BONDLINE					
Grit Blasted D6AC Steel	-20	8,572	5.1	5	99% Coh in Adh, 1% Adh
	20	7,932	4.2	5	96% Coh in Adh, 4% Adh
	75	6,925	3.3	5	89% Coh in Adh, 11% Adh
	100	5,838	6.6	5	66% Coh in Adh, 34% Adh
	125	5,120	1.9	5	83% Coh in Adh, 17% Adh
	150	4,869	4.4	5	49% Coh in Adh, 51% Adh
	200	4,119	6.0	5	62% Coh in Adh, 38% Adh
	250	3,394	4.4	5	90% Coh in Adh, 10% Adh
	300	2,122	8.5	5	71% Coh in Adh, 29% Adh
Rust-Oleum Coated D6AC Steel	-20	6,200	1.0	5	50% Coh Adh, 45% Adh Pnt 5% Coh Primer
	75	4,590	0.9	5	14% Coh Adh, 49% Adh Pnt 37% Coh Primer
	125	1,869	6.3	5	98% Coh Paint, 2% Adh Paint/Primer
	200	720	3.0	5	97% Coh Paint 3% Adh Paint/Primer
	300	475	7.8	5	87% Coh Pnt, 6% Prmr/D6AC 4% Coh Prmr, 3% Adh Paint
Cork to Rust-Oleum Coated D6AC Steel	-20	344	1.0	5	100% Coh Cork
	75	193	2.8	5	100% Coh Cork
	125	98	12.3	5	100% Coh Cork
	200	64	2.9	5	100% Coh Cork
	300	48	7.7	5	100% Coh Cork

TABLE I (CONT.)

Tensile Adhesion Button Bond Strength of EA-934NA with 2.5% Cab-O-Sil (Test Speed 0.05 inches/minute)

SUBSTRATE	Test Temp. (°F)	STRENGTH (psi)	C.V. (%)	No. Tested	Failure Mode
30-MIL BONDLINE					
Grit Blasted	-20	7,079	4.2	5	100% Coh in Adh
D6AC Steel	20	7,366	2.0	5	100% Coh in Adh
	75	6,951	8.1	5	99% Coh in Adh, 1% Adh
	100	5,872	8.9	5	91% Coh in Adh, 9% Adh
	125	3,902	11.5	5	77% Coh in Adh, 23% Adh
	150	3,685	5.3	5	66% Coh in Adh, 34% Adh
	200	3,337	11.8	5	74% Coh in Adh, 26% Adh
	250	2,976	12.6	5	81% Coh in Adh, 19% Adh
	300	1,679	5.5	5	94% Coh in Adh, 6% Adh
Rust-Oleum Coated	-20	5,801	10.1	5	63% Coh Adh, 37% Coh Pnt
D6AC Steel	75	4,975	11.1	5	53% Coh Adh, 47% Coh Pnt
	125	2,559	2.2	5	100% Coh in Paint
	200	862	4.7	5	100% Coh in Paint
	300	531	4.7	5	100% Coh in Paint
Cork to Rust-Oleum	-20	424	2.9	5	100% Coh Cork
Coated D6AC Steel	75	217	3.4	5	100% Coh Cork
	125	127	3.8	5	100% Coh Cork
	200	71	7.8	5	100% Coh Cork
	300	51	8.7	5	100% Coh Cork

LWR No's.: 594546, 563379, 595606

TABLE II

Lap Shear Bond Strength
of EA-934NA with 2.5% Cab-O-Sil
(Test Speed 0.05 inches/minute)

SUBSTRATE	Test Temp. (°F)	STRENGTH (psi)	C.V. (%)	No. Tested	Failure Mode
Grit Blasted D6AC Steel	-20	5,891	7.5	5	100% Adhesive
	20	6,085	9.0	5	100% Adhesive
	75	5,794	3.0	5	57% Coh in Adh, 43% Adh
	100	4,800	2.3	5	74% Coh in Adh, 26% Adh
	125	3,883	2.2	5	87% Coh in Adh, 12% Adh, 1% Void
	150	3,012	9.4	5	49% Coh in Adh, 51% Adh
	200	3,251	7.8	5	60% Coh in Adh, 40% Adh
	250	2,467	11.8	4	12% Coh in Adh, 88% Adh
	300	1,616	5.4	5	32% Coh in Adh, 68% Adh

LWR No's.: 595609

TABLE III

Tensile Properties of EA-934NA with 2.5% Cab-O-Sil

TEST TEMPERATURE (°F)	X-HEAD SPEED (IN./MIN.)	STRENGTH (PSI)	C.V. (%)	MODULUS (KSI)	C.V. (%)	STRAIN (%)	C V. (%)	POISSON'S RATIO (10-40%)	C.V. (%)	NO. SPECIMENS TESTED
-20	2.0	10,190	3.7	736	12.9	1.66	14.0	0.334	14.0	5
20	2.0	10,580	6.0	812	7.4	1.84	11.0	0.341	20.9	5
75	2.0	9,790	1.2	769	14.4	2.41	13.8	0.367	10.3	4
100	2.0	8,190	4.4	689	6.8	2.35	5.2	0.361	15.1	5
125	2.0	4,260	8.9	436	14.3	2.16	14.3	0.295	19.3	5
150	2.0	4,680	2.7	243	15.3	10.47	5.4	0.292	6.0	4
200	2.0	4,550	5.1	321	13.2	4.34	14.2	--	--	4
250	2.0	2,800	10.6	136	12.3	3.37	10.7	—	—	5
300	2.0	2,330	4.6	91	19.3	3.22	17.1	—	—	3

LWR No.: 594550

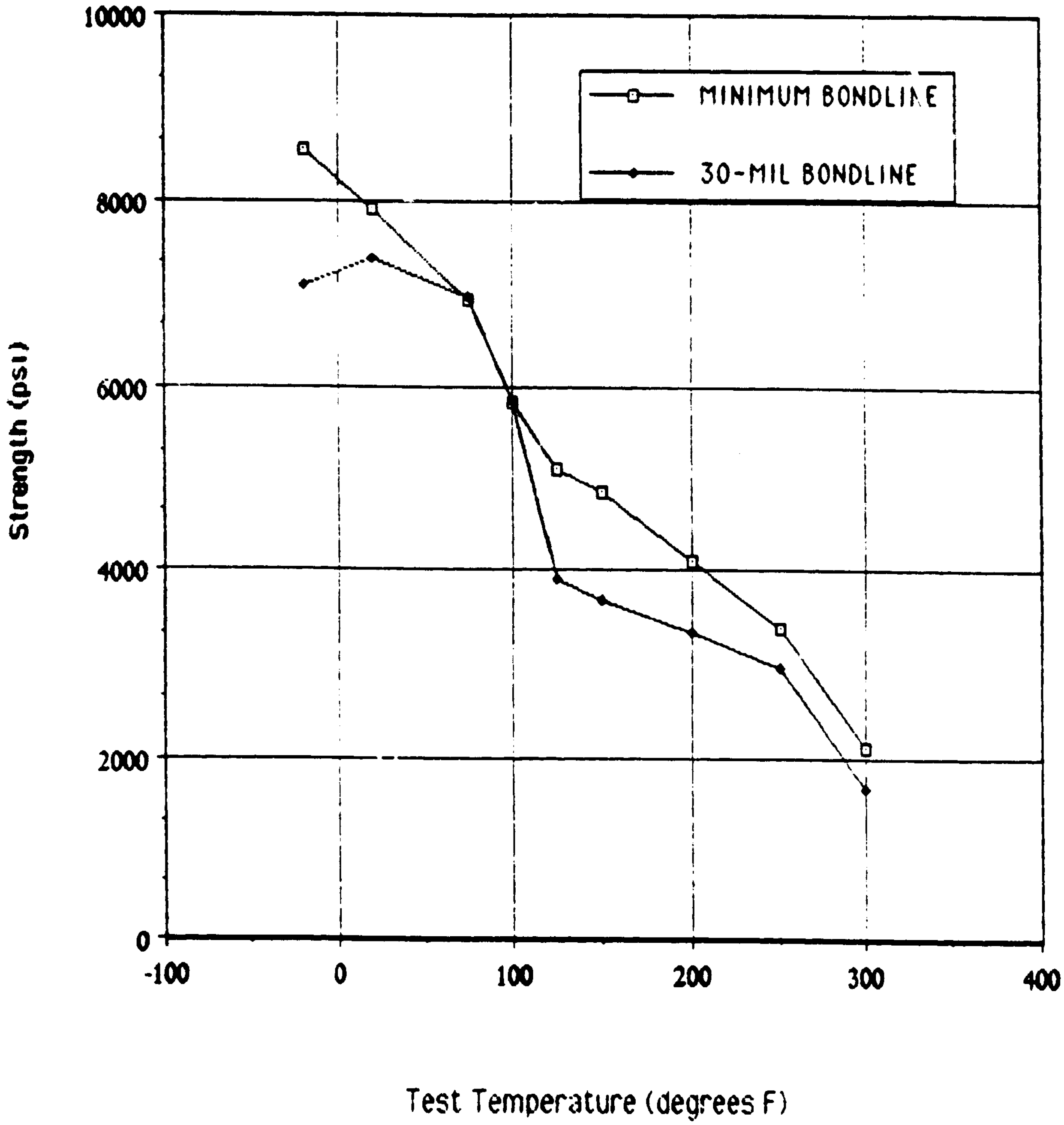

Figure 1. Tensile Adhesion Bond Strength of EA-934NA With 2.5 % Cab-O-Sil (Grit Blasted D6AC Steel Substrates)

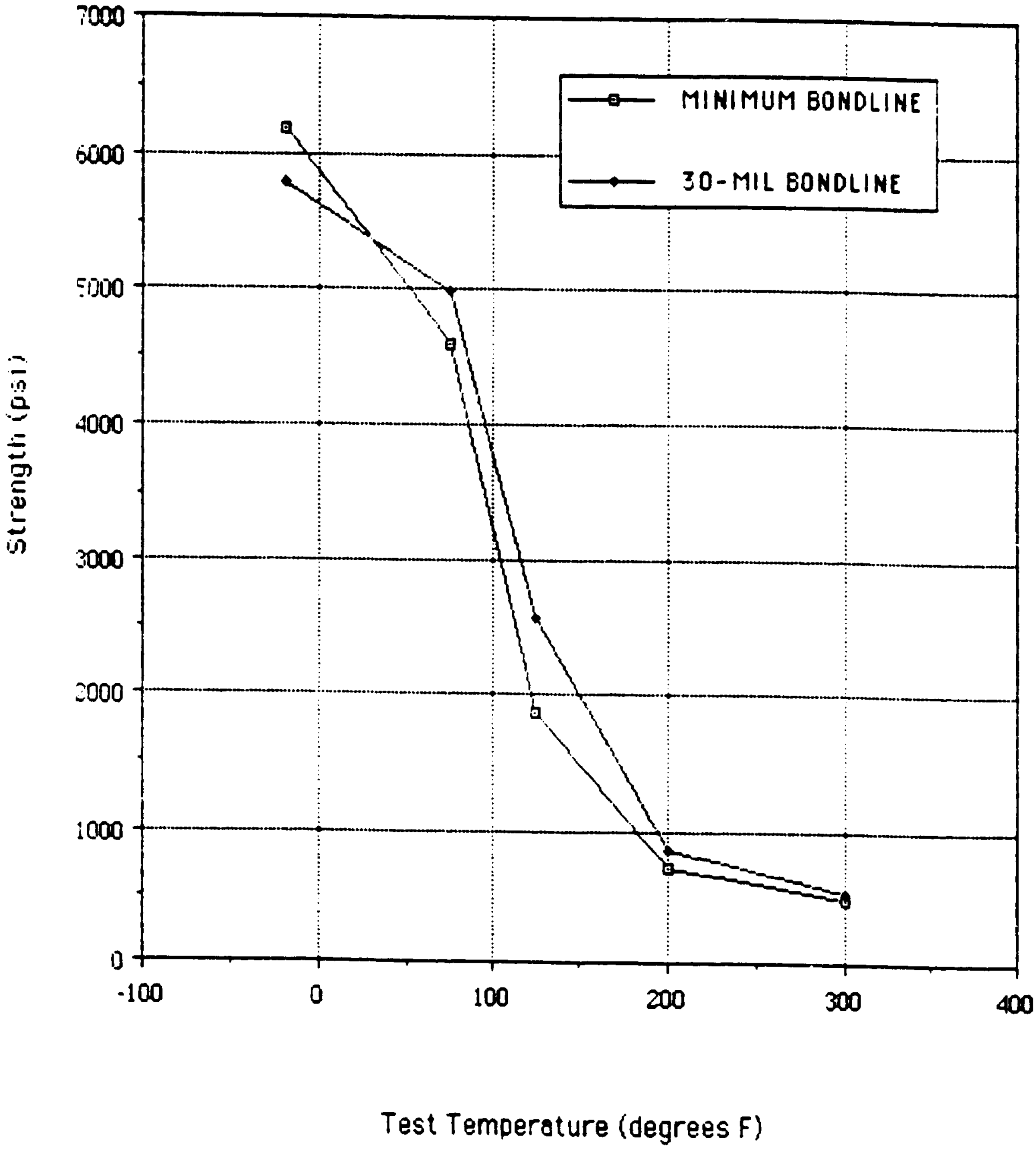

Figure 2. Tensile Adhesion Bond Strength of EA-934NA Wtih 2.5 % Cab-O-Sil (Rust-Oleum Coated D6AC Steel Substrates)

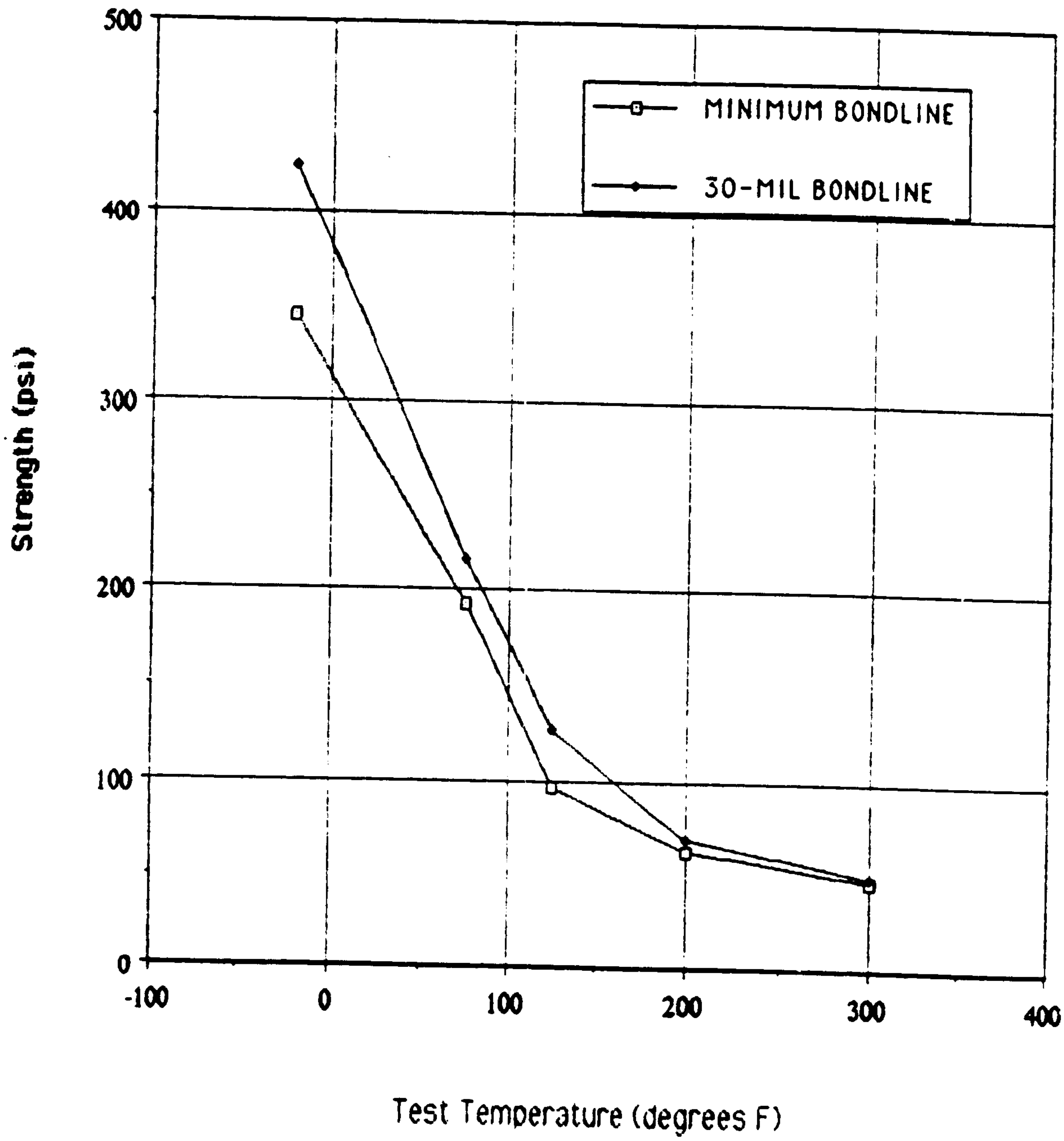

Figure 3. Tensile Adhesion Bond Strength of EA-934NA Wtih 2.5% Cab-O-Sil (Cork to Rust-Oleum Coated D6AC Steel)

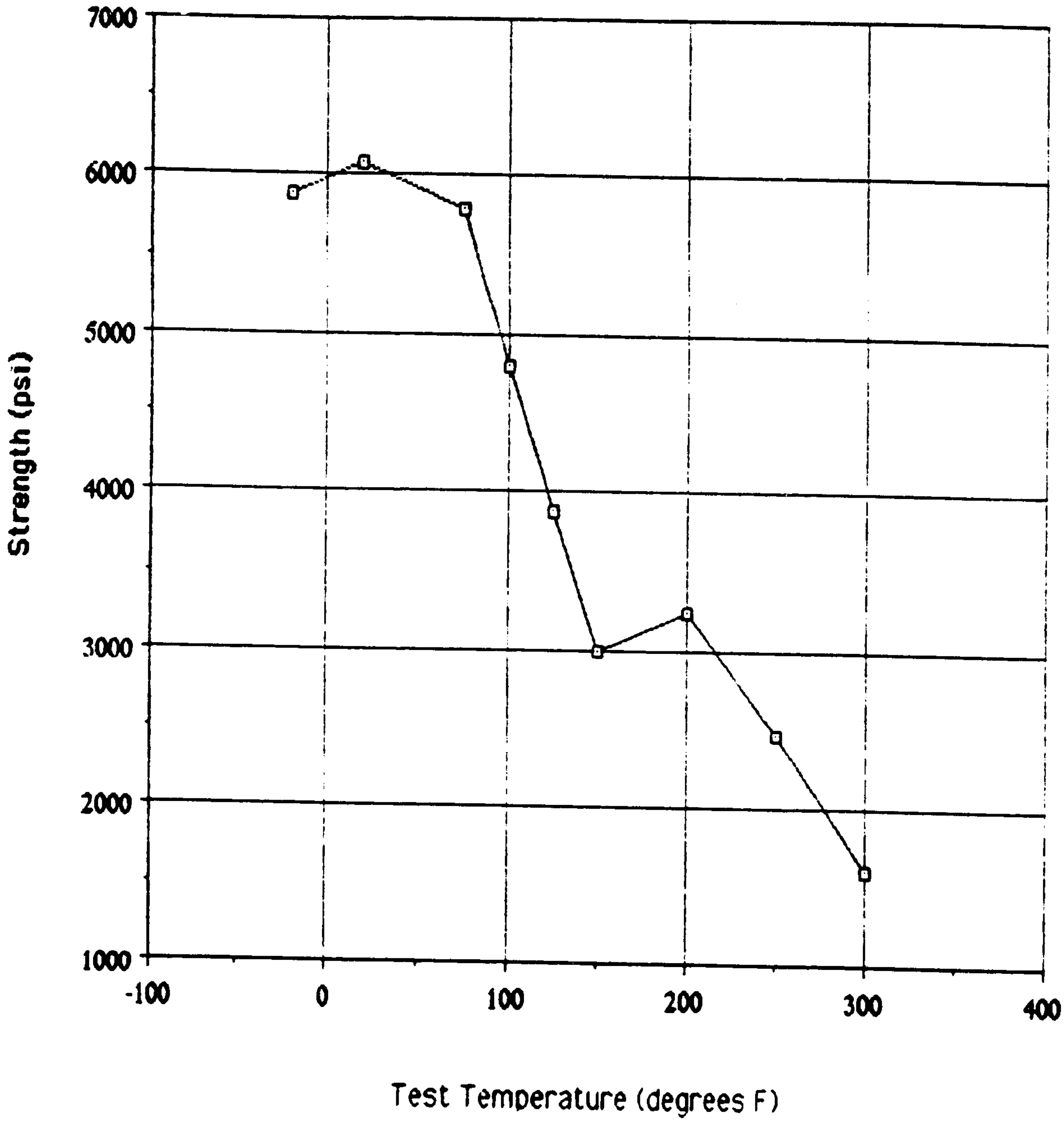

Figure 4. Lap Shear Strength of EA-934NA With 2.5% Cab-O-Sil (Grit Blasted D6AC Steel Substrates)

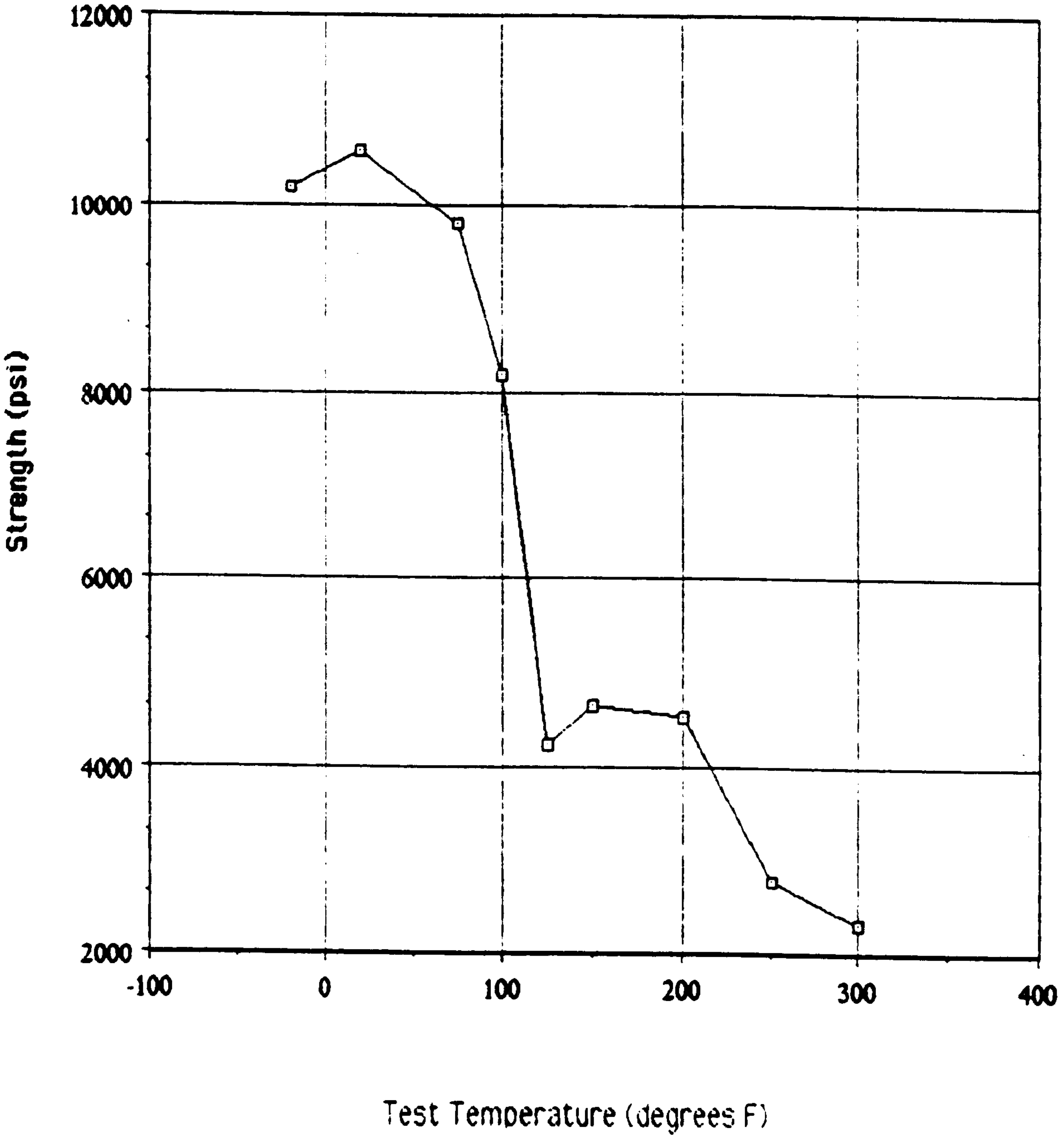

Figure 5. Tensile Strength of EA-934NA With 2.5% Cab-O-Sil (2.0 In/Min)

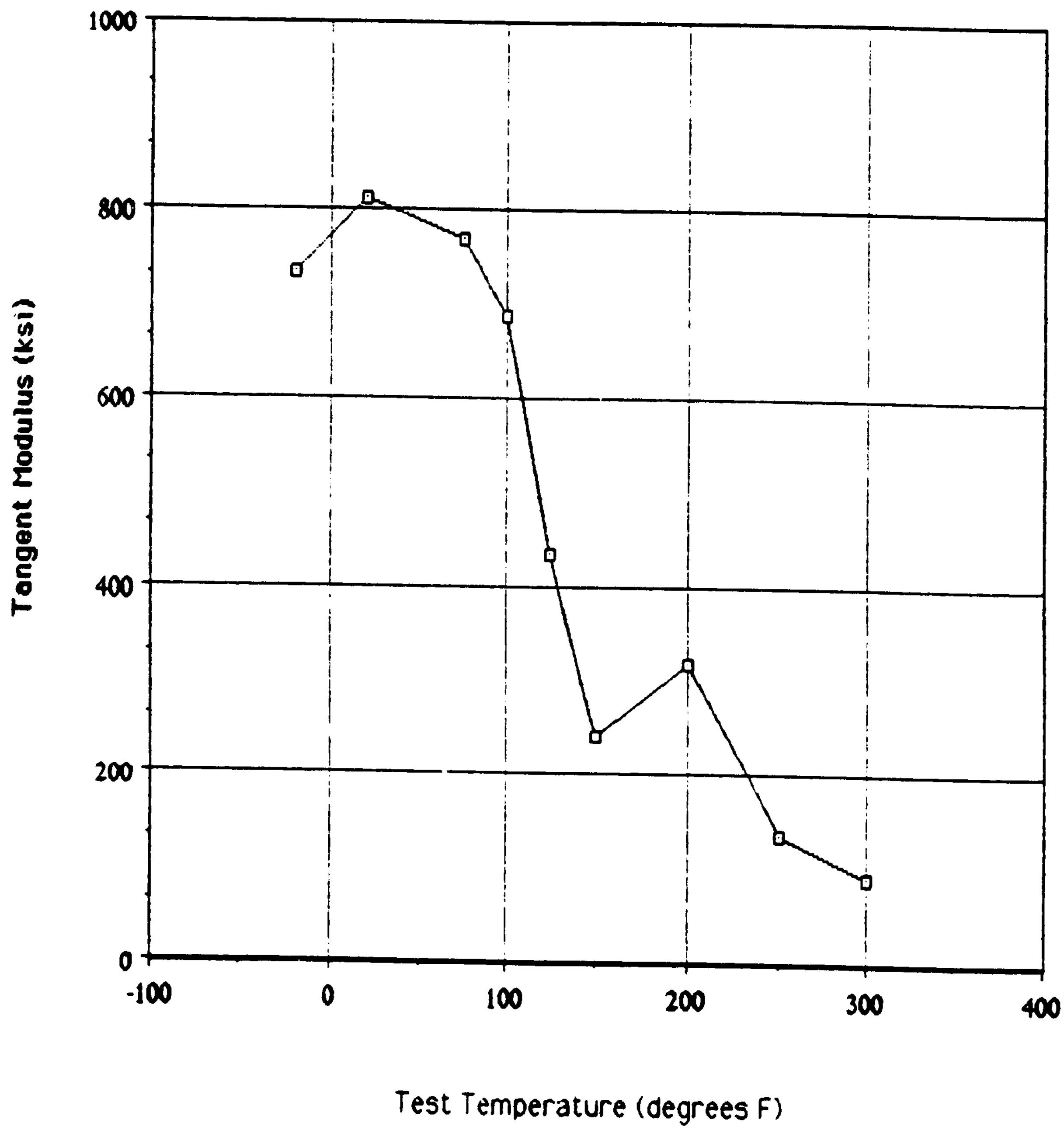

Figure 6. Tangent Modulus of EA-934NA With 2.5% Cab-O-Sil (2.0 In./Min)

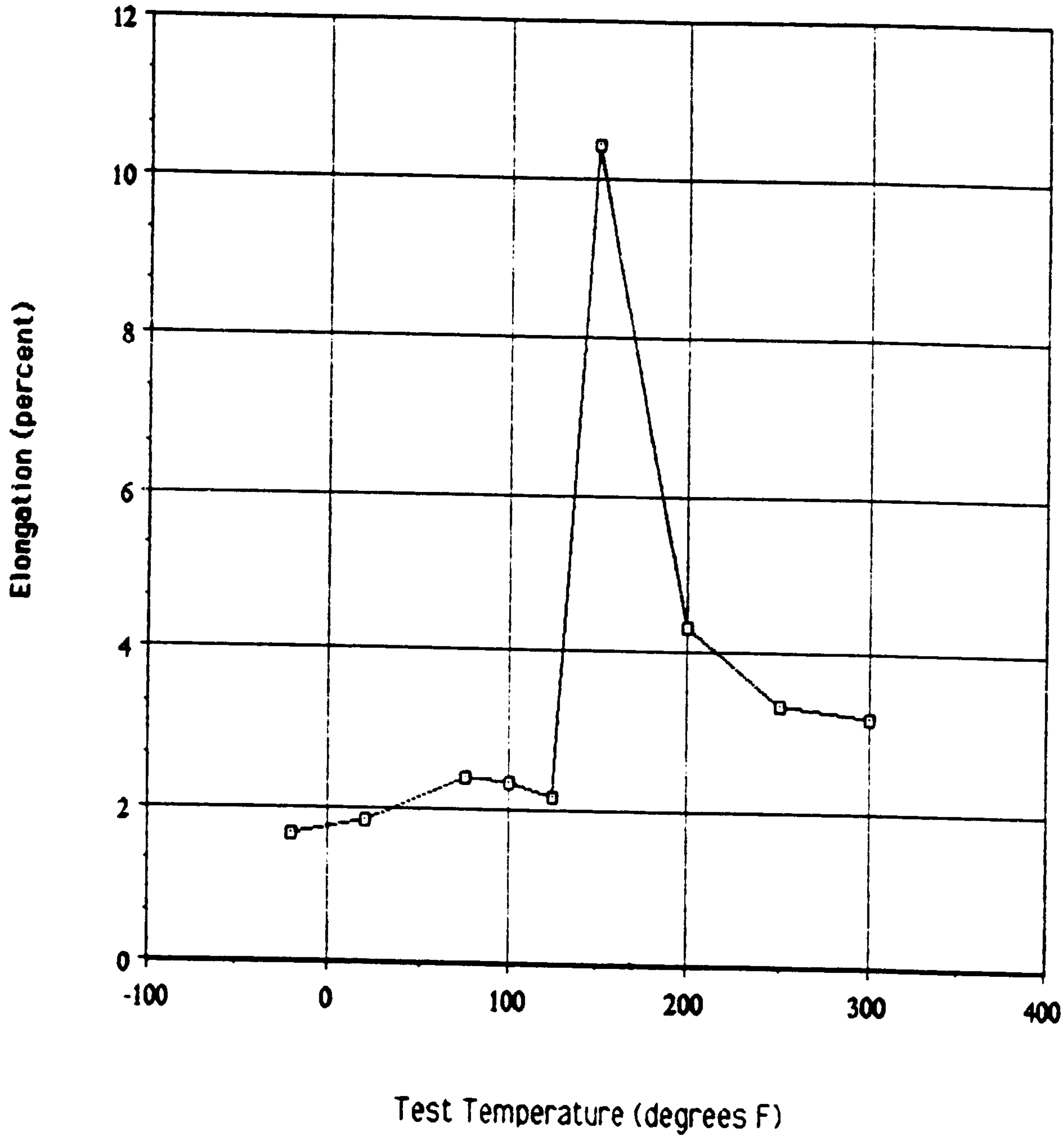

Figure 7. Elongation of EA-934NA With 2.5% Cab-O-Sil
(2.0 In./Min)

Distribution	M/S
C. W. Bown	E80
B. F. Bradford	E80
G. A. Caldwell	243
K. R. Eckhardt	E80
R. S. Jensen	L62A
L. W. Poulter	243
L. E. Seidner	E80
G. L. Stephens	E66
C. W. Whitworth	E80
Technical Library	Q52A
M&P File	E80